PHYSIOLOGICAL RESPONSES OF WOMEN *AND* MEN TO EXERCISE INDUCED HEAT STRESS IN FIREFIGHTING GEAR

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INTRODUCTION

Firefighting involves performing strenuous physical work in heavy (approx. 20 **kg),** protective clothing. The combination of exercise, the weight, insulative properties, and low moisture vapor permeability of tlie gear, and tlie external lieat load places a considerable pliysiological stress on the body. Because of its central role in metabolism and thermoregulation, the cardiovascular system is largely responsible for meeting the demands of tlie physical activity and the thermal stress. During firefigliting, a competition for blood flow ensues between the metabolically active muscles and the body's heat dissipating mechanisms. If tlie cardiovascular system fails to meet tliese competing demands, heat stress injuries may occur.

Although it **is** well recognized that heat stress places a considerable load on the body, tliere are relatively few studies that have documented the magnitude of tlie pliysiological stress of performing work in firefigliting gear. Fewer studies have investigated tlie differences between the pliysiological responses of men and women while performing work in firefigliting gear, despite the dramatic increase in the number of women in the fire service. Therefore, tlie purpose of tlis study was to describe the effects of exercise-induced lieat stress in firefigliting gear on selected pliysiological variables in healthy young women and men.

METHODS

Subjects were 15 liealtliy volunteers (N=7 men, N=8 women) between tlie ages of 17 and 37 years. All subjects provided written informed consent and completed a health history questionnaire prior to testing. Tlie protocol was approved by the Human Subject's Review Board. All subjects were free of all known cardiovascular disease. The men were significantly heavier (75.9 ± 9.7 vs 61.8 ± 5.7 **kg)** and taller (178.9 ± 8.2 vs 168.3 ± 8.8 cm), and had a higher **maximal** oxygen consumption (56.7 ± 12.3 vs 44.9 ± 2.9 ml/kg/min) tlian the women who participated in this study.

A repeated measures within subject design was utilized. Subjects performed 20 minutes of stepping exercise on a Stairmaster (Model 4000) in *two* different clothing conditions; namely a **control** condition and a **gear** condition. On separate days subjects wore: (a) cotton shorts and T-shirt (control condition), and (b) firefigliting turn-out gear (bunker pants, coat, boots, helmet, hood and gloves). The order of testing was randomized. All testing was conducted in a thermoneutral laboratory.

Prior to the testing days, subjects performed a maximal, incremental work test on a motor driven treadmill until volitional fatigue. The maximal oxygen consumption (VO_2max) values obtained during the initial testing served as a descriptor of each subject's fitness level, and allowed the investigators to express each participant's submaximal workload on a relative basis. All subjects were familiarized with the stairstepping machine and the exercise protocol during the initial laboratory visit.

The testing protocol included a 4 minute pre-exercise period (resting), 20 minutes of submaximal stepping exercise and 10 minutes of recovery. Oxygen consumption was measured each minute via indirect spirometry. Heart rate was measured every minute using a 12 lead ECG (Qumton 750) which was interfaced with an automated blood pressure machine (Qumton 410) that recorded blood pressure every four minutes. Rectal temperature was recorded each minute throughout testing using a rectal thermistor (YSI, Model 511) inserted 10 cm beyond the external sphincter. The probe was connected to a YSI telethermometer (Model 4000) and displayed digitally. Peak acceleration, peak velocity and stroke distance of blood in the ascending aorta was measured using continuous wave ultrasound (Exerdop; Quinton Instruments). A transducer, placed in the suprasternal notch of the subject and pointed down towards the ascending aorta, measured the frequency shift of the continuous wave between the wand and the blood being ejected from the heart. Psychological measurements were obtained throughout the testing to assess thermal distress and rating of perceived exertion. Perceptions of thermal sensations were measured every four minutes using a scale developed by Young et al. (1987) with verbal anchors ranging from unbearably cold to unbearably hot. Ratings of perceived exertion (RPE) were measured every four minutes during the 20 minutes of exercise using the *6-20* Borg scale (Borg, 1985).

RESULTS

All subjects completed the 20 minutes of stepping exercise in both conditions. Table 1 presents the values obtained during the control trial and during the firefighting turnout gear trial. The oxygen consumption, expressed relative to body weight (ml/kg/min), did not vary significantly between the sexes for either the control or gear trial. However, because the women had a lower VO_2max, they were working at a significantly higher percentage of VO_2max *than* the men for both conditions.

Heart rate, oxygen consumption, thermal distress and ratings of perceived exertion were higher for both sexes when the exercise was performed in the turnout gear. Additionally, the women had a higher systolic blood pressure when the work was performed in the gear condition. Rectal temperature at the end of exercise was not significantly different between trials. None of the Doppler variables (peak acceleration,

Table 1 End-exercise values for both sexes under both conditions. (Mean ± 1s.d.)

	MEN		WOMEN	
	Control	Gear	Control	Gear
HR (bpm)	133.7 (19.7)	168.4 (27.2)[a]	151.1 (11.5)	178.4 (9.9)[a]
VO_2 (ml/kg/min)	24.2 (3.2)	29.1 (5.4)"	23 (1.5)	28 (1.9)[a]
VO_2 (% of max)	43.6 (5.7)	52.5 (10.3)[a,b]	51.4 (4.3)	62.7 (5.8)[a,b]
SBP (mmHg)	171.5 (13.6)	178.5 (12.7)	153.8 (8.8)[b]	169.4 (9.6)"
DBP (mmHg)	69.6 (10.5)	70.3 (12)	78.1 (12.7)	79.9 (12.6)
Tc (C)	37.7 (0.5)	37.8 (0.5)	37.8 (0.3)	37.9 (0.3)
PkA (cm/s/s)	38.3 (8.4)	48.4 (16.4)	36.8 (17.6)	48 (14.5)
PkV (cm/s)	1.2 (.2)	1.2 (0.1)	1.04 (.3)	1.2 (0.3)
TVI (cm)	12.9 (2.5)	10.6 (2.4)	9.68 (3.2)	11.2 (1.9)
TD	5.25 (.3)	6.8 (0.6)"	5.1 (0.7)	6.7 (0.5)"
RPE	13 (1.4)	15 (1.3)[a]	12.3 (1.6)	14.8 (1.5)[a]

[a] $p < .05$; Control **vs.** Gear

[b] $p < .05$; Men vs. Women

peak velocity, time-velocity integrals) were significantly different at the end of the gear trial compared to the control trials. However, peak acceleration was approximately 25% higher following the gear trial for both men and women. The time-velocity integral, on the other hand, was approximately 18% lower at the end of exercise in the gear trial for the men and approximately 16% higher at the end of exercise in the gear trial for the women. The failure of rectal temperature to increase significantly is likely related to the relatively light workload and the short duration of the exercise task

Despite the fact that women were working at a higher percentage of VO_2**max**, there were no significant differences between the sexes for heart rate, oxygen consumption (ml/kg/min), blood pressure, rectal temperature, Doppler variables or psychological variables at the end of exercise in the gear condition. Despite the lack of statistical significance, the heart rates at the end of exercise was 17 bpm higher for women than for men at the completion of the exercise in the control condition and 10 bpm higher than the men's at the end of the gear trial.

DISCUSSION

Heart rate and oxygen consumption are greater when exercise is performed in firefighting gear than when the same exercise is performed in shorts and a **T-shirt.** This is due to the weight, insulative properties and low moisture vapor permeability of the clothing. Furthermore, the ratings of thermal distress and ratings of perceived exertion mimic the physiological variables (Smith et al, **1995).** The results of this study suggest that when men and women perform the same absolute submaximal workload for short periods in firefighting gear they respond in a similar manner. This is consistent with other data that suggests that men and women of similar fitness respond to exercise in hot environments in the same way. In fact, the slightly higher heart rates seen in the female subjects in this study are most likely related to the fact that they had a lower VO_2max and were therefore working at a higher percentage of VO_2max. It should be noted that the exercise duration was short and that greater differences *may* be evident following prolonged exercise.

It is interesting to note the different trends in the male and female response for the time-velocity integral. Assuming that aortic diameter is unchanged throughout the testing protocol, changes in the time-velocity integral parallel changes in stroke volume (SV = cross-sectional area of aorta times TVI). The trend for stroke volume to be lower at the end of the gear trial in males is consistent with published data that suggests that stroke volume is lower when exercise is performed in a hot environment versus a themoneutral environment (Rowell, 1974). The trend for stroke volume to be higher at the completion of the gear trial in females is more difficult to explain. It is possible that this finding is related to an earlier and more profuse sweating in males (Avellini et al, 1980). A greater sweat loss could cause a reduction in left-ventricular end diastolic volume, thereby leading to a decrease in stroke volume (Coyle & Montain, 1993). This trend warrants further investigation.

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